A SUMMARY OF THE YEAR'S WORK AT MOUNT WILSON[1]

By George E. Hale

The 100-inch Hooker telescope, yielding results that are of service in all departments of the Observatory's work, has remained a center of interest thru-out the year. In light-gathering power, in the photographic registration of minute details of structure, and in the separation and measurement, by Michelson's interference method, of double stars previously unresolved, this instrument has responded admirably to a wide variety of tests. Thru its aid we have been enabled to carry our researches into new and profitable fields, thus considerably enlarging our research program. Before fixing the details of this program, it has seemed advisable to determine in what ways the capacity of the telescope could be most fully utilized, and for this reason much attention has been given to experiments with promising accessory apparatus and methods.

By far the most significant of the auxiliaries thus developed is Michelson's interferometer, which promises to play an important part in the future of sidereal astronomy. Its possibilities in this field were clearly foreseen and fully described by Michelson in 1890, and one of them was successfully tested by him in his measurement of the satellites of *Jupiter* in the following year. The fact that no astronomical applications of the method have since been made is not easily explained. Astronomers acquainted with the extreme sensitiveness of the interferometer, and constantly hampered by atmospheric disturbances, have naturally feared that differences in optical path would obliterate the fringes. But it turns out that they can be clearly observed with large apertures even when the seeing is poor.

A crucial test was made on September 18, 1919, when Professor Michelson, at the first trial on *Altair*, had no difficulty in seeing the fringes with the full aperture of the 60-inch and 100-inch telescopes. The essence of the method lies in the use of two slits, symmetrically placed on either side of the axis of the telescope, and so mounted in a rotating support that their distance apart can be varied. As the mirror is otherwise covered, the only light entering into the focal image is that which passes thru the slits. The conditions are thus

[1]From the Annual Report of the Director for the year ending Aug. 31, 1920.

precisely analogous to those of Fizeau's classical experiment, in which two pencils of light, derived from a single point source, are brought to interference. Observed with a high power eyepiece (2000 to 10,000 diameters) the fringes appear as sharp, narrow lines, on a fluctuating background. In a case like that of the close double star *Capella*, the components of which, about $0''.05$ apart, are not visible in any telescope, there are two independent sets of fringes, one due to each star. On rotating the disk carrying the slits, the visibility of the fringes is seen to vary with the position angle. When the line joining the slits corresponds with the line joining the stars, the slits are separated until the fringes of one set fall exactly between those of the other, causing minimum visibility, or complete disappearance if the two stars are of equal brightness. The distance between the slits then permits the angular distance between the two stars to be computed with a precision greatly superior to that attained in the micrometric measurement of wide binaries. As an indication of this precision, it may be added that the greatest difference between the observed and calculated positions of the components of *Capella*, as determined by Mr. Anderson, is four hundred thousandths of a second of arc. An account of the method, describing the technique developed by Mr. Anderson for the measurement of both position angle and distance, may be found in *Mt. Wilson Contribution* No. 185. It is hoped that thru a co-operative plan of observation, in which other observatories will take part, a large number of close binaries may be measured by the interferometer.

The simple use of two slits permits the theoretical resolving power of the Hooker telescope to be more than doubled under ordinary atmospheric conditions, and this result can be still further improved by attaching a large interferometer to the upper end of the telescope tube. An instrument of this sort, in which two plane mirrors, used instead of slits in combination with the 100-inch mirror, can be separated to a distance of twenty feet, has been built in our shop and tested on stars by Professor Michelson. The sharpness of the fringes observed with this enormous resolving power, which corresponds with the theoretical resolution of a telescope of about forty feet aperture, indicates that atmospheric difficulties would not be likely to stand in the way of a much greater extension of the method. It remains to be seen whether it will

prove feasible to accomplish Professor Michelson's desire to measure the angular diameter of a star.[2]

The truly extraordinary precision of measurement attained in the case of *Capella* naturally raises the question whether a comparable advance can be accomplished in the measurement of stars several minutes of arc apart. If this were feasible, the determination of parallaxes and proper motions might be greatly improved, and it might become possible to measure the displacement of a star caused by the gravitational field of *Jupiter* (Einstein effect). Professor Michelson has designed several forms of interferometers for this purpose, and one of them will soon be tested with the Hooker telescope. It is feared, however, that atmospheric disturbances, which would differ along the optical paths of stars several minutes apart, may prevent the fringes from being observed.

Professor Michelson's work as a Research Associate of the Observatory will be continued and extended in various directions. In addition to his investigations on the astronomical applications of the interferometer he has undertaken a new determination of the velocity of light by an improved method, which promises results of the highest accuracy. Preliminary tests made this summer over a distance of about four miles were so satisfactory that a range of sixteen miles is now being tried, and it is hoped that it may prove feasible to use in the final work a still greater distance between stations.

The area of the 100-inch mirror is about 2.8 times that of the 60-inch, and the Hooker telescope, under perfect atmospheric conditions, should theoretically reach stars about a magnitude fainter than we have been able to observe with the smaller instrument. This advantage has been fully attained in spectrographic observations under good conditions, thus permitting an important extension of our investigations of stellar spectra. To determine whether an equal gain can be secured in direct photography, a series of comparative photometric tests has been made. These indicate that

[2]Since the above was written, on December 13, 1920, Mr. Pease succeeded in measuring the diameter of *α Orionis* with the 20-foot interferometer. The interference fringes were found to disappear when the mirrors were moved apart to a distance of 10 feet, corresponding to an angular diameter of 0″.046 for the star—a result in close agreement with Eddington's theoretical value of 0″.051. In making the reduction, λ5500 was assumed to be the mean wave-length of the light of *α Orionis*, but this is only provisional, as the exact wave-length must be determined by measurement. A more accurate value of the distance between the mirrors corresponding to the position of minimum visibility will be obtained as soon as the means of moving and adjusting the mirrors has been improved. It should be added that the adjustments were tested at the ten-foot position by turning the telescope to two other stars, of small angular diameter both of which showed the fringes perfectly. A full account of the work will be published by Messrs. Michelson and Pease in the *Astrophysical Journal.*

with seeing 6 on a scale of 10, stars nine-tenths of a magnitude fainter than those reached by the 60-inch can be photographed with the Hooker telescope during the same exposure time. Moreover, the details of the Moon's surface and the minute structure of nebulae are much better shown with the larger instrument. Thus the most exacting and rigorous comparative tests, made simultaneously under identical atmospheric conditions, using plates from the same box, developed in the same tray, prove conclusively that the Hooker telescope has met our highest expectations.

The increased light-gathering power of the new instrument should add several hundreds of millions of stars to those already known. For certain classes of work, a further advantage can be attained by means of a simple device due to Mr. Shapley, who mounts a converging lens system a short distance in front of the photographic plate, thus concentrating the starlight in a smaller "tremor-disk" thru a virtual reduction in the focal length of the telescope. The gain in light-gathering power over the 60-inch telescope, used without this device, is more than two magnitudes. While the field is necessarily limited thru the interposition of the lens, this method has already proved its value in the investigation of star clusters and nebulae. Another useful device for the study of the faint stars in crowded clusters is a large prism, mounted before the plate at the 134-foot Cassegrain focus.

In this connection mention should be made of the visit of Professor Wright, who brought his slitless quartz spectrograph from the Lick Observatory in June in order to try it at the Newtonian focus of the Hooker telescope. Excellent preliminary results were obtained, and it is hoped that he may be able to continue this work at some time in the near future.

The 100-inch telescope affords an exceptional opportunity for measuring the radiation of faint stars, and of determining the spectral-energy curves of brighter ones. Dr. Abbot's long experience with the bolometer especially qualifies him for this work, which he will undertake as soon as his other duties permit. Meanwhile the problem has been approached from a different direction with the aid of a thalofide cell—a new device for the measurement of radiation in which the sensitive substance, fused on a quartz disk and mounted in an evacuated tube, is composed of thallium, oxygen and sulphur. The maximum sensitiveness of this cell, which makes it especially useful for certain observations, is at 10,000 angstroms.

The preliminary tests made by Messrs. Shapley and Benioff with the 100-inch telescope are promising, and the work will be continued with improved instrumental arrangements.

In connection with the experiments made last year by Messrs. Anderson and Babcock on the polarization of the light of the sky by day and night, an extremely sensitive means of detecting very slight traces of polarized light was developed. This device is being used with the Hooker telescope by Mr. Hubble in an attempt to determine whether the light of certain nebulae shows any indication of polarization.

Finally, altho no new instrumental accessory has been required for the purpose, a word may be added regarding the striking phenomena rendered visible on the Moon's surface by the aid of the stereoscope. The very sharp lunar photographs made at the 134-foot focus of the Hooker telescope by Mr. Pease serve admirably for this purpose when pairs representing the same phase, but differing in libration, are combined. The distinct appearance of relief thus brought out should aid materially in the solution of lunar problems.

Other additions to the equipment of the Hooker telescope are in prospect, and the development of this instrument has already advanced so far that we are now able to complete the details of our general research program, some of the chief elements of which were indicated in the last annual report. While considering the most promising lines of attack on stars and nebulae, the possibilities of the solar and laboratory work have been re-examined, with the object of perfecting a homogeneous and well-balanced general scheme. In this connection the completion of the remodelled Snow telescope and its accessories for work with the Fabry-Pérot interferometer, and the addition of several important instruments to our laboratory equipment, have been essential factors.

Full details of the work of the year may be found in the body of this report, but the chief investigations in progress may be briefly summarized here. Of exceptional current interest is the bearing of the solar wave-length determinations of Messrs. St. John and Babcock on the generalized theory of relativity. It will be recalled that the careful investigations of Mr. St. John have failed to show a systematic shift of solar lines toward the red of the magnitude predicted by Einstein. Evershed has also failed to find the desired displacement, but the importance of the question is so great that no pains should be spared in settling it beyond the peradventure of a

doubt. For this reason Messrs. St. John and Babcock have renewed their attack with improved apparatus, involving many refinements of procedure overlooked by less careful spectroscopists, some of whom have found no difficulty in confirming Einstein's prediction. Exceptional weight will certainly be deserved by conclusions based upon the admirable methods described in this report, in which direct spectroscopic determinations of wave-length are checked by wholly independent measures obtained with the aid of a Fabry-Pérot interferometer.

The measured displacements of stars photographed near the Sun by the British observers during the total solar eclipse of May 29, 1919, are of such precision, and in such close correspondence with the demands of the theory of relativity, that the validity of the conclusions based upon them does not appear open to question. Confirmatory evidence of the same kind is much to be desired, however, and for this reason it is hoped that the Michelson interferometer may prove to be suitable for the measurement of the small displacement of stars by *Jupiter* called for by the theory. The difficulties arising from atmospheric disturbances may perhaps prove insuperable, but a serious effort will be made to apply the method.

The solar activity continued to decline during 1919, and at present the Sun is remarkably free of spots. The consequent absence of disturbing local fields has permitted us to renew our study of the Sun's general magnetic field, and Mr. Ellerman has taken a large number of photographs of spectra for this purpose during the summer of 1920. These will usefully supplement the plates secured during a favorable interval in 1916, which Mr. van Maanen's recent measures show to confirm within narrow limits the period of 31.52 days found for the rotation of the Sun's magnetic axis in 1914. No high-latitude spots have yet appeared as forerunners of the next cycle, and we still await the opportunity to determine whether the reversal of magnetic polarity observed at the last minimum is to be confirmed.

At Mr. Abbot's request, Mr. Nicholson has undertaken a comparison of the variations in area of the dark hydrogen flocculi (prominences photographed in projection on the Sun) with the variations of the solar constant of radiation. Clayton's recent success in basing weather predictions on changes in the solar radiation directs renewed attention to the importance of finding a corre-

sponding correlation of these short-period fluctuations with other classes of solar phenomena, and Mr. Nicholson will give special attention to this subject.

The Mount Wilson photographic map of the sun-spot spectrum, on a scale of one centimeter to the angstrom, has been completed by Mr. Ellerman for the region $\lambda 3900$–$\lambda 6600$. This scale, supplemented by the use of a Nicol prism and compound quarter-wave plate over the slit of the 75-foot spectrograph of the 150-foot tower telescope, suffices to separate the components and to show the polarization phenomena of many lines affected by the magnetic field. The numerous band lines, and the changes of line intensity due to the reduced temperature in spots, are also well shown. The map should prove of service in solar and laboratory investigations and in the study of red stars under high dispersion.

The infra-red region of the solar spectrum, rendered accessible by the use of plates sensitized with dicyanin, has been photographed by Mr. Brackett as far as $\lambda 9900$. The great majority of the 550 lines measured are of terrestrial origin, but thru the detection of their displacements produced by the solar rotation, Mr. Brackett has identified about 50 solar lines.

Our investigations of nebulae have been considerably extended, and now embrace a wide variety of objects. Mr. Pease and Mr. Duncan have continued to photograph nebulae of interest with the 60 inch and 100-inch telescopes, with special reference to proper motions and the problem of rotation in spirals.

Provisional measures by Mr. van Maanen of 32 points in the spiral nebula M 33 indicate the presence of internal motions analogous to those previously found in the case of M 101, namely, an outward motion along the arms of the spiral. The number of points for which this general result does not hold is so small that it may be accepted as the characteristic feature of the motion. The photographs compared were both taken with the 60-inch reflector, one by Mr. Ritchey ten years ago, the other by Mr. Duncan in August. The mean motion of the nebular points for the 10-years interval, relative to the comparison stars, is about $0''.2$, which is of the same order as that found in the case of M 101.

Mr. Hubble has made a study of the three known variable nebulae, one of which (N. G. C. 6729) has shown decided changes within a single day. These remarkable objects do not appear to give indications of actual motion: from the available evidence their

variation seems to be the result of irregular brightening and obscuration of a nebulous background. Mr. Hubble has also taken numerous long exposure photographs with the large field of the 10-inch photographic refractor and a camera of 6 inches focus for the purpose of determining the distribution of the dark markings on the sky. The results suggest that they lie on a plane inclined at a small angle with the galactic plane, and coinciding with that of the local cluster of B stars. Measures of the color-indices of Herschel's nebulous stars by Messrs. Seares and Hubble show that these interesting objects are much redder than ordinary stars of the same spectral type, presumably because of the scattering of their light by their nebulous surroundings, tho other explanations may be suggested. Another investigation bearing on the nature of spiral nebulae and the problem of "island universes" has also been made by Mr. Seares. This consists of a determination of the surface brightness of the galactic system as it would appear from a distant point in the direction of the galactic pole. It turns out that the surface brightness of all known spirals is greater than that of the Galaxy: in some of the brighter ones the proportion is about one hundred to one. Thus if these objects are really systems of stars, they must differ greatly from our own system in the relation of stellar density to linear dimensions.

Some years ago Professor Kapteyn derived a first approximation for the laws of stellar luminosity and density. In the meantime a large amount of material has been accumulated and much work has been done in the direction of perfecting our knowledge of these laws, which are fundamental as an expression of the constitution of the galactic system. Much still remains to be done before a complete solution can be given; but a second approximation has now been finished by Professor Kapteyn, Research Associate of the Observatory, with the collaboration of Dr. van Rhijn. It is still necessary to treat all spectral types together and to regard the system as symmetrical about an axis, with the Sun at or near the center. The luminosity curve has now been carried well past the maximum, which corresponds to an intrinsic brightness 2.9 magnitudes fainter than that of the Sun. A Gaussian error curve represents the distribution of the luminosities with an extraordinary precision over a range of more than 18 magnitudes. Professor Kapteyn's investigation has made it possible to give for the first time an indication of the variation of stellar density with galactic latitude, as well as

with distance. The results are most reliable in the direction of the poles of the Galaxy. In this direction the density falls to 0.01 of its value near the Sun at a distance of about 1200 parsecs, while in the galactic plane this value occurs at a distance of about 9000 parsecs. The curves of equal density are much flattened and emphasize anew the structural importance of the Galaxy. A full account of this investigation may be found in *Mount Wilson Contribution* No. 188.

Planetary nebulae, especially on account of the resemblance of their spectra to those of novae and variable stars, are of great interest in the study of stellar evolution. The extensive investigations of these objects at the Lick Observatory render another general attack unnecessary, but there are certain particulars in which we may usefully supplement the work at Mount Hamilton. Mr. van Maanen's measures of the parallax of the central stars of planetaries, indicating their faint absolute magnitudes and showing their distances to be of the same order as those of novae, are cases in point. Including five of these objects, 22 new trigonometrical parallaxes have been completed this year, making 122 in all. A few spiral nebulae are included in the list, tho not with the expectation of finding measurable parallaxes.

The magnitudes of all stars recorded by the 60-inch reflector in exposures of fifteen minutes on Kapteyn's Selected Areas Nos. 1-139 have been completely measured and reduced under the direction of Mr. Seares. The results are being prepared for publication in connection with Professor Kapteyn's magnitude determinations for the same areas on plates of longer exposure, the first large instalment of which has been received.

The continuation of Mr. Shapley's investigations of star clusters has added further arguments in support of his view that the galactic system is very much larger than was formerly supposed from considerations based on the brighter stars. If his conclusions are correct, the brightest stars in globular clusters must be giants; if the other view is sound, they must be dwarfs.

This question, on which evidence had already been secured from a study of the spectra of certain of the brighter stars, photographed by Mr. Pease with a slit spectrograph, has been further tested by the aid of the device already mentioned—a large prism, of small angle, mounted near the 134-foot focus of the Hooker telescope. The continuous spectra of the stars in clusters, from $\lambda 3800$ to $\lambda 7500$, are thus photographed on Ilford panchromatic plates, on which well-

known giants and dwarfs, of determined spectral type, are also photographed for comparison. The distribution of light in the spectra of the brightest cluster stars corresponds with that of known giants of the same spectral type as the cluster stars, and is characteristically different from that of known dwarfs.

The fainter stars in clusters are hardly less interesting, and the use of an intensifying lens with the Hooker telescope has enabled Mr. Shapley to photograph much fainter objects than could be reached formerly. He has also continued his studies of globular and open clusters, analyzed the characteristics of 1152 giant stars in nine clusters, and determined the total intrinsic luminosities of forty globular clusters, which he finds, on the average, to give 275,000 times as much light as the Sun.

Mr. Shapley's investigation of the faint globular cluster Messier 72 has revealed the presence of many variables, 26 of which have been studied, giving the light-curves and periods characteristic of Cepheids of the cluster type, and indicating that the distance of this very remote cluster is 83,000 light years. Assuming the validity of Eddington's theory of the radiative equilibrium of a giant star, he has derived theoretically a period-luminosity law for Cepheids, and concludes that the average heat content per unit mass is nearly identical for all of these stars having periods longer than three days.

The continuation of the systematic investigations of stellar spectra by Messrs. Adams, Joy, Merrill, Sanford and Strömberg, assisted during the past year by Messrs. Duncan and Hoge, has yielded 135 new determinations of (constant) radial velocity and the orbits of five new spectroscopic binaries. Both the 60-inch and the 100-inch telescopes have been employed, the former chiefly for the absolute magnitudes of stars brighter than the 8th magnitude, the latter for the study of fainter stars, including those with very large proper motions, Md stars, faint Cepheids and Algol variables, novae and miscellaneous objects.

The reductions of Mr. Adams's determinations of stellar luminosity and parallax have been finished during the year, and the complete tables will be published within a few weeks. The spectroscopic method of measuring parallaxes has proved increasingly satisfactory, and the detailed comparison of the results with the best trigonometric parallaxes indicates a very high order of precision. The tables provide data for many interesting discussions, some of which are also in preparation for publication.

Much attention has been devoted by Mr. Adams and his associates to the spectra of temporary stars, and many new and interesting phenomena have been observed. In *Nova Lyrae*, for example, the displacements of the two components of the hydrogen lines on February 5th were in the ratio of 2 to 1, while the oxygen and nitrogen lines were shifted by the larger of these values. Displacement ratios of 3 to 2 and 2 to 1 were noted in the last annual report for the components of the hydrogen lines in other novae, and the discovery of a similar phenomenon in the spectrum of the variable T *Pyxidis* may prove to be of significance in the development of the theory of temporary stars. As the spectrum of T *Pyxidis* in April also showed other close resemblances to that of a nova at an intermediate stage, the question of possible relationship will be closely pursued.

The interesting phenomena observed in the spectrum of *o Ceti* and the discovery by Mr. Merrill of the characteristic nebular lines in the spectrum of R *Aquarii*, emphasize the necessity of directing renewed attention to the spectra of variable stars in all stages of brightness. Nebulium has not been found previously in any stellar spectra except those of novae, and it is very important that many other Md stars be observed near minimum, when the nebular lines, which in R *Aquarii* do not appear to change in brightness, should be most easily detected. The Hooker telescope affords the necessary light-gathering power for such observations, which will be included in Mr. Merrill's general investigation of the Md stars. The radial velocities of 46 of these stars have now been determined, making a total of 90 thus far known. The mean systematic difference between the radial velocities, as measured with the bright and dark lines, is about −20km; and the average motion given by the bright lines, if truly representative, is the greatest of any class of stars and does not differ materially from that of the planetary nebulae. This coincidence, and the close resemblance of the spectra of planetaries with that of R *Aquarii* near minimum, are suggestions that will not be overlooked in future work.

Turning now to the Pasadena laboratory, mention should be made of several important additions to its equipment. These include a 500 K. W. direct-current generator set, which greatly increases the range of our investigations with the arc, electric furnace, and other light-sources calling for heavy current; a special solenoid magnet for the Zeeman effect, designed to carry a current

of 4000 amperes, now nearly ready for trial; a new electric furnace for the study of emission and absorption spectra at high temperatures; a 2-inch concave grating mounted for use as an auxiliary dispersion piece for work with the Fabry-Pérot interferometer; and a large condenser and other apparatus for the production of explosive discharges through fine wires.

Mr. King's electric furnace investigations have been extended to include the rich spectra of several of the rare earth metals and the infra-red region of iron and manganese. The cyanogen band at λ3883 has also been photographed in absorption for measurement in connection with Mr. St. John's work on the Einstein effect in the Sun. As the question has been raised whether the sensitive high-temperature lines of the furnace require electrical conditions, rather than high temperature alone, for their production, the new 500 K. W. generator has been employed in testing this point. Several different means were adopted to maintain the high temperature and at the same time to reduce or completely eliminate the potential difference, and all were alike in indicating that the low potential differences involved are without effect on the spectrum.

With the object of imitating the spectroscopic phenomena which must accompany the fall of a meteorite into the Sun, Mr. Anderson has exploded fine wires by the discharge of a large condenser. The resulting light-source, attaining a brightness more than one hundred times greater than that of the Sun and a black body temperature of some 20°,000 C., is of great interest spectroscopically. The absence of the principal enhanced lines, and the reversal of the spectrum far into the red, indicate the desirability of pushing this investigation further.

The same condenser has been used by Messrs. Anderson and Babcock to produce brilliant and very violent sparks for spectroscopic study. The extreme characteristics of the spark spectra of iron, titanium, chromium, and nickel have thus been determined for the region λ3000—λ7200.

The measurement of over 600 standards of wave-length in the spectrum of iron has been completed by Mr. Babcock with the Fabry-Pérot interferometer for the region λ3370—λ6750, and the work is being carried toward longer and shorter wave-lengths. Mr. St. John has covered the same region with the higher dispersion of a long-focus grating spectrograph, which permits the wave-lengths of a much greater number of lines to be measured. The

results will be published together, as the errors of these two methods are complementary. It is expected that the excellent agreement of the results will help to eliminate the difficulties that have delayed the adoption of international standards of wave-length. Several American physicists are arranging to co-operate with the international committee of which Mr. St. John is Chairman, and a large number of wave-length determinations will be made by both methods.

The measurement of solar wave-lengths with the highest precision is an operation demanding the most rigorous precautions, especially in view of the errors ordinarily involved in the comparison of two light-sources. For this reason the use of four different methods of observation, and especially the pains that are being devoted to fixing the exact positions of telluric and iodine standards for comparison with solar lines, are of special importance. Not only the Einstein effect, but many other questions are in the balance, and extensive laboratory investigations are necessary in dealing with them. Thus the Fabry-Pérot interferometer is being employed to measure the wave-lengths of lanthanum, barium, calcium, cerium, and strontium lines, and displacements caused by pressure and by pole-effect in the arc are being determined with the highest possible precision.

Other laboratory investigations have included the determination of the wave-lengths of oxygen and nitrogen lines given by metallic sparks in the red and infra-red; photographic observations of the spectra of condenser discharges in high vacua; and various miscellaneous studies.

Construction work has been limited chiefly to the erection of a wing of the Pasadena laboratory to contain the 500 K. W. generator and its switch-board; a large underground tank for the cooling system of the new solenoid magnet; the completion of the observing platforms for observers at the principal and Cassegrain foci of the Hooker telescope; installation of the constant-temperature control system for the 100-inch mirror; and the various additions to instrumental equipment already mentioned. The Hooker telescope is now essentially complete, but work on its accessory instruments will be continued as long as new and promising devices are in view.